Renewable and Sustainable Energy Reviews 14 (2010) 1379–1389

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

South Korean citizen's preferences on renewable energy support and cooperation policy for North Korea

Hwa-Young Sin *, Eunnyeong Heo, Sul-Ki Yi, Jihyo Kim

Department of Energy Systems Engineering, Seoul National University, 599, Gwanang-no, Gwanak-Gu, Seoul 157-742, Republic of Korea

ARTICLE INFO

Article history:
Received 15 December 2009
Accepted 15 January 2010

Keywords:
South Korea
North Korea
Renewable energy
Energy cooperation
Majority voting
Citizen preference

ABSTRACT

To solve the continuing North Korean energy problem, the international community has provided, almost continuously, energy aid such as heavy fuel oil. Despite the large amount of energy aid North Korea has received, there is no evidence that the North Korean energy problem has gotten any better. Unless there is an structural energy reconstruction within North Korea, it portends the energy crisis there will only be exacerbated. Thus, North Korean energy solution cannot continue to remain at the level of providing direct aid, but should encompass a sustainable energy system that can answer the North's energy needs in mid- to long-term. Seeking a more permanent solution to solve the North Korean energy crisis, we contend renewable energy (RE) is a suitable option that can be used to build a sustainable energy system that North Korea can self-manage. From the South Korean energy policy perspective, that could be used to provide mid- and long-term energy solution for North Korea and fundamentally solve its energy crisis, this research sought to assess the South Korean residents' preferences on burdening the cost associated with implementing a South Korean Government (SKG)-led RE support and cooperation policy for the North. We conducted a survey to assess the majority voting trends and approximately 30% of the respondents answered they had "no desire to pay." The result showed that it would be difficult to fund an energy policy by making the South Korean populace directly shoulder the cost.

Contents

1. Introduction

North Korea's food and energy shortage has been a long-pending problem for the Northeast Asian security. To solve the North's energy problem, the international community has

* Corresponding author. Tel.: +82 2 880 8705; fax: +82 2 882 2109.
E-mail addresses: lovesin7@snu.ac.kr (H.-Y. Sin), heoe@snu.ac.kr (E. Heo), skyi@snu.ac.kr (S.-K. Yi), frogpri1@snu.ac.kr (J. Kim).

1364-0321/$ – see front matter
doi:10.1016/j.rser.2010.01.009

provided, almost continuously, energy aid such as heavy fuel oil. In fact, energy and food aid to the North as an incentive to the denuclearization is discussed as one of the most important facets of the Six-Party Talks and Northeast Asian regional security.

Despite the large amount of energy aid North Korea has received, there is no evidence that the North Korean energy problem has gotten any better. Unless there is a significant structural reform within North Korea, it portends the energy crisis there will only be exacerbated. Thus, North Korean energy solution cannot continue to remain at the level of providing direct aid, but should encompass a sustainable energy system that can answer the North's energy needs in mid- to long-term.

Seeking a more durable solution to solve the North Korean energy crisis, we contend RE is a suitable option that can be used to build a sustainable energy system that North Korea can self-manage. As a part of the Seoul National University's continuing research to determine the most appropriate RE source, from the South Korean energy policy perspective, that could be used to provide mid- and long-term energy solution for North Korea and fundamentally solve its energy crisis, this paper will seek to assess the South Korean residents' preferences on burdening the cost associated with implementing a South Korean Government (SKG)-led RE support and cooperation policy for the North. In the course of doing so, we will first explore the causes of the North Korean energy crisis; factors affecting the provisioning of energy aid to North Korea; and RE source suitability and current status of RE research, development, and utilization within North Korea.

2. North Korean energy crisis and its societal impact

The primary energy source for North Korea is coal. It relies on hydro- and coal-powered plants to generate most of its electricity (Fig. 1). The energy production level in North Korea decreased drastically since the 90s, and it has not been able to return to pre-1990s production level (Fig. 2). Reasons contributing to this decrease in energy production include natural disasters and supply and demand imbalance. Despite North Korea's efforts, the energy production level has not improved and it has led to contraction of industrial output as well as its economy.

The North Korean energy problem has actually been discussed since the early 1980s. Energy consumption in North Korea increased exponentially since the 70s due to its industrialization [1]. The energy supply decreased noticeably during the "arduous march" due to faltering production levels. The combination of increased energy demand and decreased energy production pushed the North Korean energy problem into a full blown crisis. Similar to the North Korean food problem, the factors that contributed to its energy crisis are: (1) large-scale natural disasters; (2) fall of the Soviet Union; (3) decrease in energy production capability; and (4) general economic stagnation. The three major deficiencies and problems (energy, food, economic crisis) in North Korea are not independent from each other. These problems are interdependent and mutually affect each other – food shortage leads to reduced labor pool and efficiency; which leads to overall depression of industrial productivity; which (since the energy production is also an industrial sector) leads to

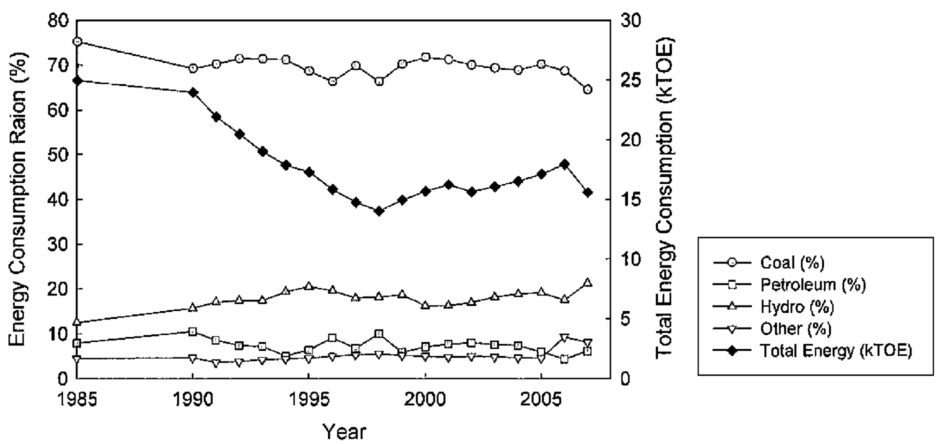


Fig. 1. North Korean primary energy usage status (Data Source: Bank of Korea).

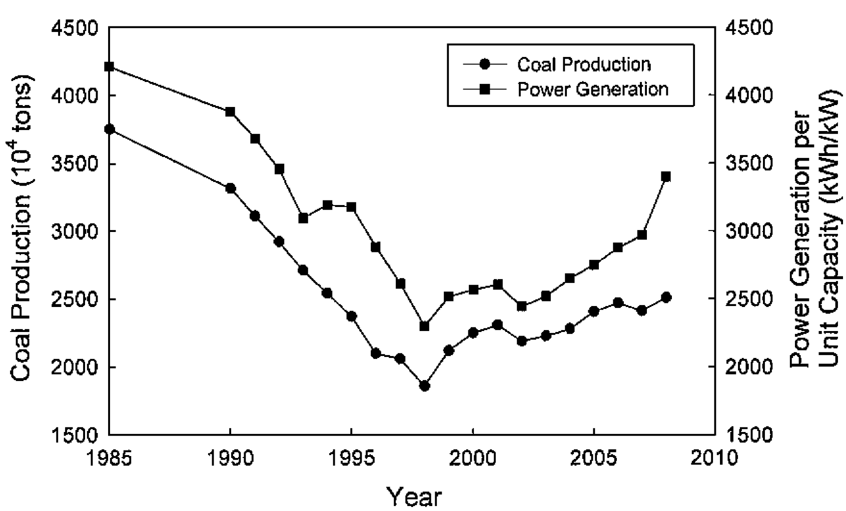


Fig. 2. Estimated North Korean coal production and power generation (Data Source: Office of Statistics).

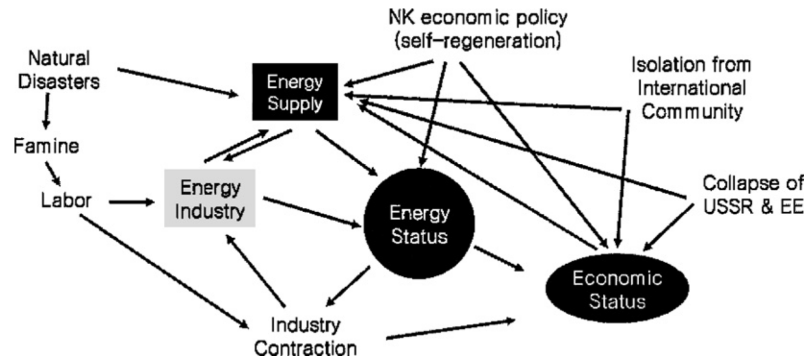


Fig. 3. Relationship between North Korean energy, food, and economic crises.

decreased energy production [2]. Of course, lack of energy supply has direct effect on the industrial production and economic activity levels. Energy is used as raw material for production and fuel; therefore, energy shortage causes decrease in production; which in turn leads to decrease in productivity and profit; which then in turn leads to economic stagnation – it is truly a vicious cycle of circumstances.

Natural disaster is one of the primary reasons directly responsible for shortages in food and energy production between the 90s and 2008. Rapid and uncontrolled deforestation of mountains in North Korea, which started in 1973 to secure large quantities of farmland and to meet the growing energy needs for industrialization, led to enormous soil erosion with devastating results [3]. Soil erosion caused the coal mines to collapse or wash away under severe weather conditions and the amount of soil washed away into the rivers affected hydropower generation tremendously. Fig. 3 explains the intricate and complex relationship these factors have on each other.

3. International politics and assistance: current status and problems associated with North Korea

The LWR project of KEDO was not only an energy aid program, but it also included a technological support element. There are numerous different opinions on the reasons which contributed to the failure of the LWR project; however, technologically, due to the decrepit North Korean energy infrastructure, the use of LWR would have only been possible after constructing a brand new electric grid that is capable of handling 10 times the amount of electricity generated in North Korea [4]; therefore, even if the LWR construction was completed, it would have been next to impossible to bring the LWR online.

In 2007, North Korea received promise from the five other participating members of the Six-Party Talks that it will receive heavy fuel oil (HFO) in return for denuclearization, and has received it starting July of 2007. Table 1 is the amount of HFO North Korea has received as of December 2008.

Even with the HFO donation, it is virtually impossible to provide North Korea with the amount of HFO needed to make a difference in the energy situation due to lack of storage facility in North Korea. Inadequate energy infrastructure, especially the inferior electric power grid, is a major obstacle to the energy production and facility improvement in North Korea; therefore, infrastructure improvement must accompany any energy plan (aid, support, cooperation, or otherwise), or the plan must call for the use of energy source that does not rely heavily on the existing infrastructure.

Table 1
HFO supplied to North Korea (Source: CRS Report, Manyin).

Donor country	HFO (MT)
South Korea	50,000
China	50,000
USA	200,000
Russia	150,000
Total	450,000

Thus far, all South Korean and international energy plan for North Korea has been focused on resolving the immediate shortage and has not addressed fundamentally solving the crisis. International political climate, North Korea's attitude, and North Korea's internal issues are all factors why the international community has only been able to implement superficial energy aid programs that address short-term needs; therefore, any future plan being designed to resolve the North Korean energy problem in the long-term should be designed to side-step North Korea's external and internal problems. Of course, rebuilding of North Korea's energy infrastructure and environmental impact should also be considered in conjunction during the planning process. Environmental consideration should be one of the center pieces of any future energy plan since it is precisely the North Koreans' mismanagement of their environment that has contributed to much of today's energy crisis.

Energy policy for North Korea must not only include the energy aid (which is a short-term solution), but should also include energy system, which includes technology and facilities. In reality, North Korea could have acquired the foundation needed to solve its energy problems from South Korea through technology transfers and infrastructure expansion; however, North Korea did not take advantage of these opportunities and has caused the energy aid programs to be of short-termed and of limited effectiveness.

Below are some of the prerequisite conditions that must be met to improve the energy programs based on the past experiences with North Korea:

- South Korean energy support and cooperation program to North Korea should be conducted in the spirit of true cooperation and on humanitarian level, and it must have a strategic plan that can guarantee success.
- Direct energy transfers (i.e. provision of heavy fuel oil) do not impress upon North Korea its need for systemic change. In fact, it provides North Korea a justification to maintain status quo.
- The long-term solution must be sustainable and must be able to resolve the fundamental reason for the energy crisis. Direct energy transfers do not solve North Korea's fundamental problem, and they are not sustainable. Policy of direct energy transfer not only does not resolve North Korea's chronic energy shortage, but it also does not provide it with its most needed transportation fuel.

- To properly and successfully implement an energy plan, North Korea must first construct appropriate energy infrastructure – North Korea must first increase its energy production efficiency; repair, modernize, and expand its energy infrastructure.
- Energy technology and facility support and cooperation is a long-term solution to solving North Korea's energy problems. Energy cooperative projects with North Korea could provide technology transfer opportunities from South Korea. Simple and direct assistance methods do not have the benefits of technology transfer and facility support; however, support programs such as energy facility construction or energy resources development projects can serve to solve North Korea's energy crisis and also have indirect benefits in the form of energy technology transfer.
- North and South Korea can establish sustainable energy production and supply systems and co-develop energy technology through cooperation.

4. Appropriateness of RE for North Korea

Prior to examining the South Korean residents' preferences on burdening the cost associated with implementing a SKG-led RE support and cooperation policy for the North, let us first inquire into the appropriateness of RE for North Korea as a localized energy system, coincidence with existing North Korean domestic energy policy, and North Korea's environmental conditions.

4.1. Localized energy system

RE infrastructure that can be decentralized is an excellent option for North Korea given the age of the existing North Korean energy infrastructure, issues that arise from direct energy transfer, and the need to distribute the energy to small-scale industrial complexes and residential homes. Research conducted in China and India have shown that RE is more cost effective and more sustainable in the remote areas of these countries than constructing a power generation facility along with all the necessary infrastructure to distribute the generated power, to meet the areas' energy needs [5–7]. Diesel fuel or other energy source needed to produce power in small-scale power generation facility are scarce commodities in North Korea and there are numerous obstacles in providing North Korea with such energy sources; therefore, RE sources can be used to provide North Korea with power production by going "off-grid."

4.2. Consistent with existing North Korean domestic energy policy: National Five-year Plan of Science and Technology Development

Under the principle of self-reliance (Juche), North Korea has been focusing on resolving its energy crisis only using domestic resources and it has previously determined that RE is absolutely consistent with its Juche policy; therefore, it has already shown great policy interest in this arena.

North Korea began developing RE such as wind, tidal, hydro, and solar power beginning in 1993 with the establishment of Non-Conventional Energy Development Center (NCEDC) and the launching of National Non-Standing Renewable Energy Commercial (NNREC). In 1998, the North Korean government integrated RE into its energy development plan, outlined the National Five-Year Plan of Science and Technology Development – North Korea was preparing to execute the said five-year plan as of 2002 [8]. This plan aims to promote research and development of RE; human resource training; increase public awareness on the importance of new energy and energy saving; and a center of excellence that will oversee training and diffusion of such new technology [9]. Recently North Korea has proactively sought out RE related technology, equipment, facility, and training from numerous foreign energy related organizations and corporations through various means.

4.3. North Korean environmental condition

North Korea's estimated energy potential for each RE source is as follows:

- Wind power: North Korea's environmental condition is assessed to be very suitable for wind power. The North Korean government created the wind energy team in 1978 [10] and has been gathering data on wind power for over 20 years. The data showed North Korea's annual average wind speed is above 4.5 m/s in 18% of the country and these areas can accommodate up to 4 GW capacity wind farms. According to preliminary survey, this translates into a potential energy resource of 1.7 TWh [11]. Given this data, wind energy has the potential to cover approximately 20% of the total North Korean energy demand over the long-term.
- Tidal Energy: The west seashore of North Korea is one of the well-known tidal zones in the world. There are 11 locations along the North Korean west coast that can accommodate tidal power generators, and has the potential to generate 4.7 million kW. On the other hand, the Nautilus Institute estimated North Korea's potential tidal energy capacity to be approximately 7 million kW. If that is the case, at 31% of full capacity, 19 TWh can be generated annually from tidal energy.
- Solar Energy: North Korea has a fairly favorable solar condition with an annual solar irradiation of 1200 kW/m^2. Its annual sunlight duration is 2400 h and 55–60% of the year is clear. With a 5-m^2 PV (0.5 kW) panel installed in each household, solar generation capacity across the country is estimated at 2.5 million kW.
- Hydro Energy: North Korea has an abundant hydro potential for large-, medium-, and small-scale hydropower generation [12] – North Korea is already utilizing much of its medium- and small-scale hydropower (MSHP) generating potential. MSHP is widely distributed throughout the country and approximately 30% of them have the potential to be developed into medium–small-scale hydropower stations.

5. North Korea' current RE status: foreign assistance and North Korea's internal efforts

5.1. North Korea's efforts to develop and distribute RE

North Korea has shown a great interest in wind power as a solution to solve its energy crisis, and has been working diligently to increase the total amount of power generated using it [10]. North Korea started its development and diffusion of wind power plants starting in 1997, and as of 2004 electricity generated by wind had reached 3 MW per annum. However, most of the wind farms in North Korea are of small-capacity standalone systems which are capable of generating less than 10 kW [10,13,14]. There are approximately 1000 small-capacity (50 W and 1 kW) wind farms along the West Coast of North Korea and approximately 200 in the Southwest area of Pyongyang (of which approximately 190 out of 200 are in operation today). Due to wind direction, maintenance and sustainment costs, and technological issues, however, the wind farms are not yielding expected results. North Korea is currently planning on constructing a wind farm with a total capacity of 200–300 MW (equipped with windmills capable of producing over 100 kW) in ChaMaTae, YangDok County, South Pyongan Province, where average wind speed is 18–20 m/s [11]. North Korea produces 5–75 kW windmills domestically and plans to increase the annual production to 5000–10,000.

North Korea's aim is to be producing 500 MW of electricity using wind power by 2020 and this plan is laid out in its *Three-Step Plan* (*Three-Step Wind Power Roadmap*) [10,13,14]. According to the *Roadmap*, North Korea aims to accumulate necessary knowledge, experience, and knowhow during the *first step* on the planning, designing, construction, administration, maintenance, and sustainment of 10 MW total capacity wind farms (with 600 kW turbines). During the *second step*, the plan calls for joint projects with NGOs and international organizations to construct wind farms in Cholsan, Onchon, and Unryul. The *third step* calls for an ambitious plan to construct large-scale on and offshore wind farms.

The main issue for North Korea concerning wind power is lack of capital and technology. For North Korea, capacity building is the utmost urgent issue. Consequently, North Korea shows a great interest in scientific, technological, and information exchange with other nations [10]. *Choso'n Sinbo* reported countries such as Germany, Denmark, and Great Britain, among others, have displayed keen interests in development of wind power in North Korea, and have exhibited desires to strengthen future exchanges and cooperation with the North [15].

Hydro energy and bio-energy are the other two areas where North Korea has focused its efforts. Parallel with its policy of constructing large hydropower plants, North Korean government encourages extensive construction of medium, small, and mini hydropower plants to maximize the use of the country's hydro resources [11,16]. However, because most of North Korea's MSHP are designed, manufactured, and installed by local residents, they are woefully inefficient and are heavily affected by seasonal environmental conditions. Thus, the actual amount of power generated from these power plants far less than expected. To solve the residential and farming electricity and heating shortages, North Korea is focusing on introduction of methane gas production facilities, development and use of biomass energy, development of fermentation, gasification, and power generating systems using biomass, development of biomass direct combustion technology, and development of cultivation technology for biomass with high productivity. As a part of its biomass program, North Korea has already started building methane production centers in over 400 areas of the country [11].

On the other hand, North Korea's progress on solar and tidal energy has been minimal. North Korea is planning to build a 1-MW solar power pilot plant by 2010, and is currently developing the technology to reduce construction cost and increase plant efficiency. The construction of Nampo tidal power plant, which began with much fanfare and expectation, has reportedly been halted due to lack of funds. Currently, North Korea is reportedly constructing five small-scale tidal power plants, each with less than 10,000 kW capacity, along with construction of a pilot plant at Onjin tideland.

Geo-thermal energy remains at planning stage with Kil Zu, Myong Chon, and An Zu as possible target areas [11].

5.2. Foreign RE assistance

Agencies and organizations from foreign countries have provided RE support to North Korea in the form of research development and experiments in diffusion. Research and diffusion of wind power, in particular, has been made via such means in North Korea due to its environmental and other conditions that makes wind power very suitable. In 1986, Denmark provided two 90 kW wind turbines [17]. The Nautilus Institute of the United States began an energy project within North Korea in 1997 to solve energy problems in the rural areas of North Korea. In 1998, it installed seven wind turbines in Unha-ri, Oncheon County, South Pyongan Province [18–21]. The United Nations Development Program (UNDP) has conducted a comprehensive study on wind power in North Korea – to include examining the wind power feasibility, facility development, equipment production, energy production, market share, and policy development – via the Small Wind Energy Development and Promotion in Rural Areas (SWEDPRA).

The Global Environment Facility (GEF) has funded the RE projects in North Korea for over 15 years at a cost of 1.5 million USD [22]. In December 1992, Adventist Development Relief Association (ADRA), a US based NGO, provided small-capacity solar power generators to some of the hospitals, orphanages, and preschools in Pyongyang. In 2001, the Korea Children Campaign, a Japanese civic group, reported it installed solar panels on the roof of the childcare facility of the Taekam Farm located just outside of Pyongyang. In April 2004, a South Korean company, who was participating in the North-South environmental cooperation project, installed a 12-kW standalone-type solar power generator at the rice farms near the Soonan area of Pyongyang. This solar power generator had its battery changed in 2005 and is reportedly maintaining a 7-kW capacity as of 2008. In 2007, the World Vision installed a 1 kW, 2 kW, 3 kW, and 5 kW solar power generators in Docheo-ri, Yeontan County, North Hwanghae Province. In July 2008, Engineering Ministries International (EMI) constructed a solar heat greenhouse in Najin, North Hamgyong Province [23,24]. ADRA also constructed a 5-m^3 capacity methane facility (for heating) in Sukcheon County, South Pyongan Province through a joint research program with the North Korean Thermal Engineering Research Institute. Moreover, in January 2008, North and South Koreas reportedly was to receive assistance from the United Nations to launch a joint biogas plant project in which South Korea will send 3 million metric-tons of excrement to the North to produce electricity and fertilizer.

RE use in North Korea is still mostly in research and experimental phase and the international or foreign agency/organization aided programs are ongoing intermittently.

6. Feasibility of RE support and cooperation with North Korea

North Korea's RE technology development plans include solar power, solar heat, wind power, bio-energy, and tidal, which is very similar to South Korea's RE technology development efforts [25]. Lim and Heo conducted a research related to the selection of RE source that is appropriate to provide to North Korea [26]. They interviewed and conducted a survey of selected South Korean experts in the RE field. In this survey, they evaluated South Korea's RE related technology as well as the appropriateness of providing that technology to North Korea. The research showed the selection criteria should address South Korea's technological adequacy; feasibility of cooperation with North Korea; issues concerning technology transfer; time required to operationalize the selected technology in the North; and estimated amount of diffusion. Moreover, it showed the necessity for more study on the environmental condition of North Korea and the need to newly build, improve, and rebuild the energy infrastructure over the long-term regardless of the selected energy source. The results also showed South Korea should adopt a government-led rather than civilian/industry-led RE support and cooperation policy for North Korea.

Based on current South Korean technological adequacy, the technology that can be provided to the North within shortest amount of time, the survey showed that 75% of the experts in the RE field answered solar heat has is the best option. Solar heat can be installed and used in the North immediately given South Korea's technology level, the availability of the technology, and South Korea's possession of the complete knowledge in designing and installation (construction) of solar heat panels and associated equipment. The problem with solar heat is that before the equipment are installed, the service water infrastructure has to

be first in place and the cost of emplacing this infrastructure is estimated to be high. Furthermore, it was found the cost of energy production per unit is higher than other RE sources.

Overall, the energy source that was selected to be the most appropriate new and renewable energy technology (RET) through the expert discussion is the geo-thermal energy. North Korea is assessed to possess a large number of potential locations that is suitable for geo-thermal plants. Geo-thermal energy is relatively not a cutting-edge technology; thus, it has a small chance of technology transfer for military use. Along with these reasons, the production cost is low, and the South Korean technology level is very high for this energy source. One drawback is that there is insufficient research conducted on the exact locations suitable for geo-thermal plants and other basic information needed to construct geo-thermal stations.

Wind power, on the other hand, was found to be the most appropriate RET based on the South Korean technological knowhow, North Korea's environmental conditions and interest, and familiarity with the technology. Accordingly, North Korea has always shown a great interest in development of wind power. That is not to say that it is not interested in development of other RETs. Due to the shortage of heating energy in North Korea (aside from the shortage of power and transportation energy), solar heat and geo-thermal energy could be appropriate solution to resolve this issue.

To maximize the effects of support and to achieve desired technology transfer, South Korea must possess adequate technology to utilize and be able to produce the RETs that is being provided to North Korea. With these criteria in mind, solar and wind power had been selected as appropriate RE candidates.

Although North Korea's new and renewable industry is in its infancy, we assess it does possess strategic plans to systematically develop the industry. Unfortunately, it has been very difficult for North Korea to develop, infuse, or utilize necessary technology to make efficient use of RE thus far. This seems to be attributable to the overall societal difficulties and lack of societal capacity North Korea has been experiencing for some time [27].

Some of the major contributing factors of North Korea's difficulty in meeting its planned RE strategic development goals can be summarized as inadequate amount of material and facilities needed to conduct research and development; insufficient international cooperation in research and availability of information; inadequate training of its scientists in the field; and deficient import of high-tech skills and systems. Therefore, any RE cooperation with the North does not require an immediate introduction of systems and infrastructure, or an expansion of RE use from current level. Rather, the short- to mid-term cooperation programs must focus on building the technology development capability by sharing information, necessary technology, and equipment. Incidentally, since RE is not yet competitive in terms of economic feasibility, technological advancement and stability, technical cooperation is about the only thing that can be planned on for cooperation between Pyongyang and Seoul. In selecting the appropriate RET, it is important to ensure the cooperation with North Korea does not cause friction with international politics and regional security. A case in point is that some of the technology for solar power has been deemed to be dual-use and was prohibited from entering North Korea, causing the development of solar energy technology in North Korea difficult at best. In 2006, however, with the approval to allow civilian solar energy system to enter North Korea, it brought about some hope of technological and developmental advancement in the future. Today, cooperation as equal partners between the North and the South does not seem to be feasible nor appropriate; therefore, it would be more appropriate for South Korea to convey all necessary knowledge and knowhow (technological, developmental, etc.), as well as assistance in training the human resource needed, to the North. It is also necessary to develop a program that will promote the North-South RE development cooperation focused on providing the North with international trends and technology related information in this field [27,28].

Another factor for lackluster performance of RE in North Korea is that NGO's have been the primary organization to provide the North with such assistance [25]. Assistance from the NGO's is still relatively small-scaled and it is still much too early to adequately evaluate the effectiveness of these NGO programs. Based on the financial capacity of the NGO's, however, none of these programs can be continuously expanded or are sustainable over the long-term.

Yet another factor is that RE technologies such and wind and solar power are new technologies and do not always perform as advertised.

7. South Korean public preferences on the cost of RE support and cooperation with North Korea

To examine the South Korean public preference on RE support and cooperation with North Korea, we surveyed the public on its preference on burdening the cost for such undertaking. This survey was conducted specifically to determine the public's preference on burdening the cost for RE cooperation with North Korea and did not address the cost of any short-term energy aid such as HFO assistance, or construction of power plants through programs such as KEDO.

The survey first inquired the public stance (agree or disagree) on the appropriateness of the South Korean government to implement a policy to provide North Korea with RE as a form of mid- and long-term energy solution. It also sought to determine the public preference on the appropriate level of support and cooperation. Accordingly, the survey first sought to confirm or deny if the respondents were willing to pay directly to burden the cost of such a policy. It then sought to observe the differences in the respondents' attitudes on the RE support and cooperation based on the respondents' characteristics.

The survey consisted of multiple stages. The first stage presented the respondents with a set amount of money and inquired if the respondents were willing to pay that amount to support the policy. The next stage's question was decided upon based on the respondents' answers to the first question. The respondents are required to answer "yes" or "no" to each question at each stage. If the answer to the first question was "yes," then the second question would ask if the respondent would be willing to pay a higher amount. If the answer to the first question was "no," then the second question would ask if the respondent would be willing to pay a lower amount. The respondents would vote ("yes" or "no") on the each amount presented to them at each stage and will arrive at the minimum or maximum amounts that was pre-determined during the design phase of the survey; therefore, the final result for each respondent was reached based on the tendency of each respondent's answer to each of the survey questions rather than by the respondent simply choosing the preferred answer from a group of pre-determined answers. The essence of conducting the individual's willingness to pay survey prior to the implementation of public policy is to determine the individual preference for that policy, not the physical monetary amount (at least in principle, the dollar value of such a good could be read off an individual's preference order) [29]. To determine the majority voting tendency for bearing the cost associated with RE policy for North Korea, this research analyzed the survey respondents' residential location, age, occupation, monthly household income, and attitude towards RE.

In May 2007, 420 surveys were distributed to the 2007 RE Conference participants and 121 surveys were returned, a 28.8%

Table 2
Survey sample composition.

Category			Number of survey	Percentage (%)
Total			118	100.0
Residence location	Capital Region	Seoul	50	42.2
		Gyeonggi Province	19	16.1
	Other Region	Chung-cheong Provinces	31	26.3
		Gyeongsang Province	11	9.3
		Jeonla and Jeju Province	7	5.9
Age	20s		48	40.7
	30s		34	28.8
	40s		22	18.9
	50 and above		14	11.9
Occupation	Researcher		58	49.2
	Academic		9	7.6
	Industrial		16	13.6
	Self-employed		1	0.8
	Student		28	23.7
	Other		6	5.1
Monthly Household Income (in Million Korean Won. Approximately 1230 Won = 1 USD)	Less than 3		27	22.9
	3–4.99		44	37.3
	5–6.99		24	20.3
	7 and above		18	15.3
	No fixed income		5	4.2
Attitude on development of RE	Positive		73	61.9
	Negative		45	38.1

return rate. Three of the returned surveys were discarded due to incompleteness and 118 remaining surveys were used to analyze the results. Results follow:

7.1. Survey sample statistical data

Survey sample and statistical data was shown in Table 2. Analysis of the survey results showed that the household income level and residential location affected the answer the most. The respondents' age and occupation, on the other hand, had less impact on the outcome.

(1) Residential location

Over 40% of the respondents resided in Seoul, and when Gyeonggi Province was added (area immediately surrounding Seoul – from here forth referred to as the Capital Region), the number of respondents increased to over 58%. The results showed the residents of the Capital Region displayed vastly different tendency than those who reside outside of the region. 34% and 31.6% of the respondents residing in Seoul and Gyeonggi Province respectively answered they were not willing to pay, which was the mode preference for the respondents residing in the Capital Region. The next most manifested preferences for the respondents from the Capital Region were to pay 2000 Won (approximately 1230 Won = 1 USD) per month in support the policy, followed by 1000 Won. In contrast, for the respondents living in other areas, 1000 won was the mode preference, followed by the preference to pay nothing. Interestingly, there were more respondents residing outside of the Capital Region who preferred to pay 4000 won and less residents who preferred to pay 2000 won than those who were residing within the region (Fig. 4).

(2) Monthly household income

The analysis of the results showed the income was one of the most important factors that affect the preference of people willing to pay to support the policy. The mode monthly income level for the respondents was between 3 and 4.99 million Won (37.3% of the respondents). The remainder of the respondents' income levels were as follow, in descending order of number of respondents: less than 3 million Won (22.9%); 5–6.99 million Won (20.3%); 7 million Won and above (15.3%); and no fixed income (4.2%).

As shown in Fig. 5, the respondents with the household income less than 5 million Won or above 7 million Won had the largest ratio of respondents who preferred not to pay anything in support of the policy. For the respondents with the household income between 5 and 6.99 million Won showed

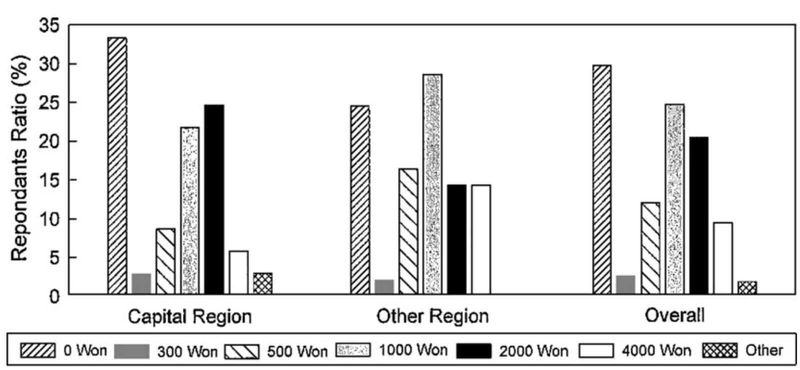


Fig. 4. Response by residential area.

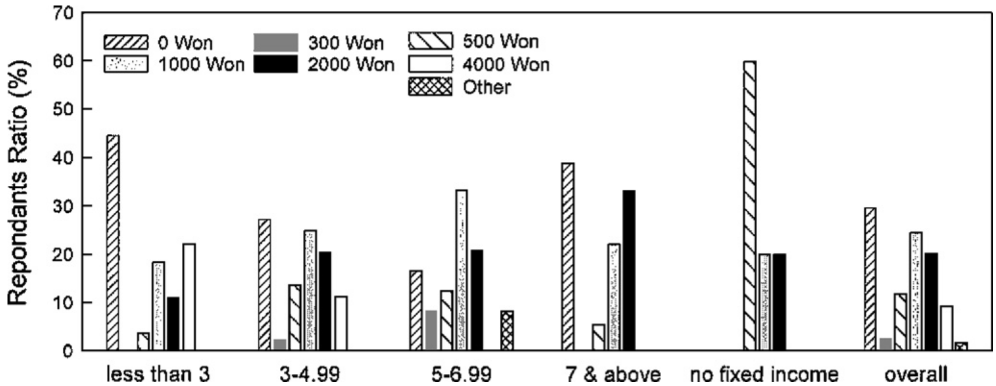


Fig. 5. Response by household income.

the most amenable tendency towards supporting the policy with preference choices of 1000 Won > 2000 Won > 0 Won.

Among the respondents who answered they were willing to pay, higher their income, higher their tendency to "vote" to pay more. An interesting data point was that all of the respondents who did not have fixed income answered they would be willing to pay in support of the policy, albeit that majority of them chose to only pay a modest amount of 500 Won. At a glance, it seems there is not an obvious correlation between how the respondents voted and their household income level; however, the results showed that the ratio of respondents who "voted" to pay over 1000 Won increases higher the respondents' income bracket, showing that if the respondent is willing to pay, then they tend to be willing to pay a higher amount in support of the policy as their income level increases. This trend is not dissimilar to the tendency of respondents without fixed income to "vote" to pay a smaller amount.

(3) Age

The mode age group of the respondents was in their 20s (40%), followed by 30s (29%), 40s (19%), and 50s and above (hence forth 50+s) with 12%.

The most striking results of the survey was that over 1/3 of the respondents in their 20s and 30s answered that they do not have any desire to pay to fund a policy that provide North Korea with RE. In fact, if one were to combined the two age groups, majority of the respondents answered they would not pay. This was in contrast with those respondents in their 40s and 50+s, which showed the "majority voting" tendency to be 2000 Won and 1000 Won, respectively. The results show that the respondents in their 40s and 50+s exhibited a much higher tendency of willingness to pay in support of the policy (Fig. 6).

Even among those respondents who were willing to pay, there were distinct generational differences. Largest number of the respondents in their 20s and 50+s, answered they were willing to pay 1,000 Won, while the largest number of respondents in their 40s said they were willing to pay 2000 Won. In fact, the 40s age group was the only group where the number of respondents willing to pay 2000 Won outnumbered those who were not willing to pay anything. Another interesting generational tendency was that for the groups in their 40s and 50+s, the number of respondents who responded that they were willing to pay either 1,000 or 2,000 Won were higher than the number of those who answered they were not willing to pay in their respective groups–The major difference between the 40s and 50+s was that largest number of the respondents in their 40s said they would pay 2000 Won while the largest number of the respondents in their 50s answered 1000 Won.

(4) Occupation

49% of the respondents were researchers. The remainder of respondents was 29% student, 14% commercial industry, 7% academia, and 6% other. A clearly high number of respondents who work in the research field or in the academia answered they would not be willing to pay in support of the policy, while relatively higher number of those who work in commercial industry and students were willing to pay. This difference can be clearly observed if one compares the answers of respondents who work in the research field and the respondents who work in commercial industry or answers of those who are students. Out of those who responded favorably to paying, same number of respondents who worked for commercial industry answered they were willing to pay 1000 or 2000 Won, which form the majority of this group. In contrast, the most number of students

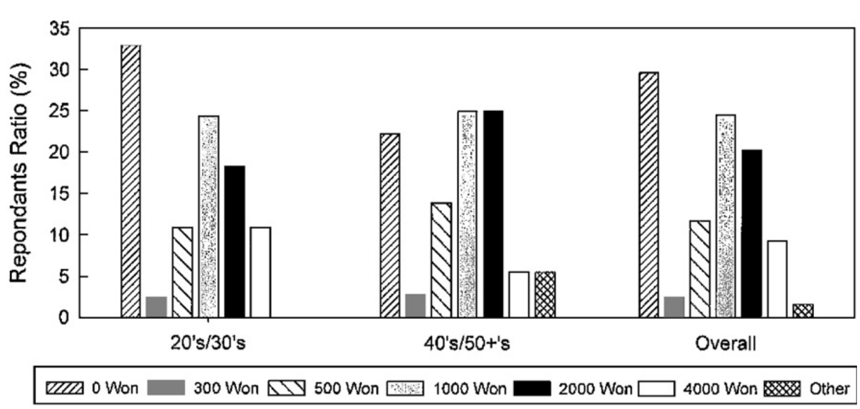


Fig. 6. Response by age group.

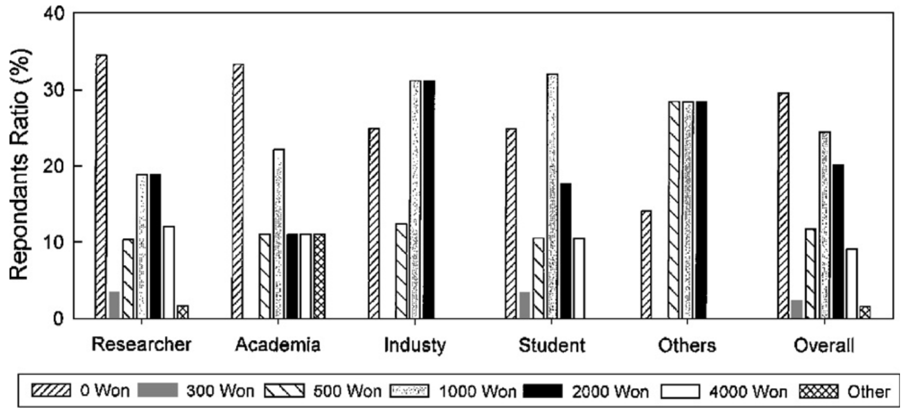


Fig. 7. Response by occupation.

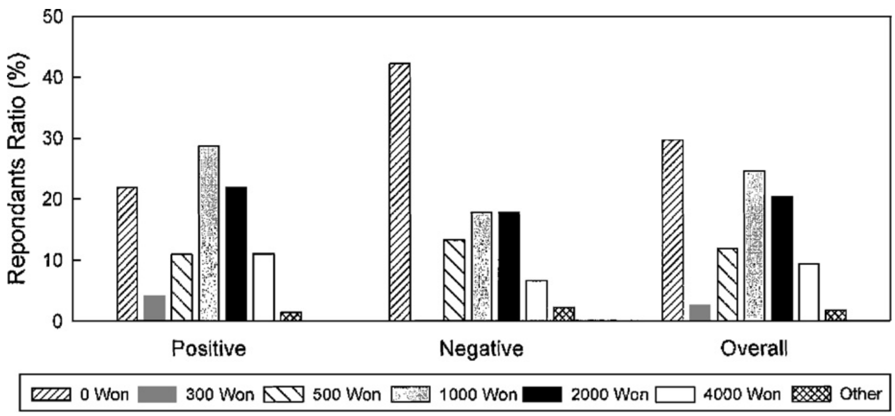


Fig. 8. Response by attitude toward RE.

answered they would be willing to pay 1000 Won and the percentages of those who answered they would be willing to pay other amounts were clearly much lower (Fig. 7).

(5) Attitude on development of RE

Of those respondents who showed a favorable attitude towards RE development and diffusion, close to 80% said they were willing to pay for the implementation of a policy that would provide RE to North Korea. Of those who showed a negative attitude toward RE, over 40% answered they had no desire to pay for the implementation of such policy (Fig. 8). Yet, for those who answered they were willing to pay, the tendency to choose how much they were willing to pay was not dependent on whether they exhibited positive or negative attitudes toward RE. In other words, a respondent's attitude toward RE only influences one's decision whether to pay or not pay, and once a person makes the decision to pay, then other factors influence how much that person would be willing to pay rather than the person's attitude towards RE.

This research analyzed the South Korean public's inclination to support a SKG-led policy for RE support and cooperation with North Korea by asking if the individuals were willing to "pay" if the policy were to be implemented.

Overall, the research shows that the South Koreans tended to respond negatively to incurring direct payment to support such a policy. Approximately 30% of the respondents answered they had "no desire to pay", and this group of respondents was shown to be the majority voting. Although the composition and method of the survey have a large influence in the outcome [30,31] this survey was constructed in such a way that it set the starting value (amount of money) at the beginning of the survey and asked the respondents whether or not they were willing to pay that amount, and if the response was negative, then it asked the respondents whether or not they were willing to pay a lesser amount (again, the set amount was given to the respondents). The value was incrementally lowered using the same method; thus, the respondents had to go through several levels of incrementally lesser value before finally arriving at the final answer of "no desire to pay." Based on this construction, the outcome that approximately 30% of the respondents responded with responses that they had "no desire to pay" portends the South Koreans at large would have a high level of disapproval for a policy where it would incur a direct tax burden on them in order to provide RE to North Korea.

As the respondents lived closer to the Seoul Metro Area, younger the age of the respondent and more negative the respondents' attitude toward RE, the majority voting was "no desire to pay." Of those who responded to this survey, 58.3% of them lived in the Seoul Metro Area and 69.5% were in their 20s and 30s. Among these groups, majority of them answered they had "no desire to pay."

Since this policy does not provide direct incentives to the South Koreans, it is difficult to justify to the South Koreans that they should bear a direct tax burden to support it. Furthermore, when querying the willingness to pay to the populace, the degree to which the populace recognizes the importance of the issue is paramount; therefore, if the populace does not recognize the fundamental value and the subtantiveness of RE support and cooperation with North Korea, then it is difficult to accurately evaluate the willingness to pay [29].

The outcome of our survey, indeed, cannot be said to have a direct connection to whether or not RE based energy support to (and cooperation with) North Korea is appropriate since the survey did not query about the appropriateness of providing RE support and cooperation itself. Since we were only interested in determining whether or not we could secure a basis for arguing that RE should be considered as one of numerous possible solutions in resolving the North Korean energy crisis in mid- and long-term, we decided to query if the public had the desire to directly bear the burden the cost incurred by implementing a policy; therefore, whether or not it is appropriate to support (and cooperate with) North Korea on energy matters, RE or otherwise, was outside of the scope of our survey. Based on our survey, we assess that it would be difficult to fund an energy policy by making the South Korean populace directly shoulder the cost; therefore, it would be more appropriate to seek a funding mechanism where the cost is indirectly paid for by the populace.

Thus far, the funding for the North Korean energy aid from South Korea has been paid for through *South-North Cooperation Fund*. In 2007, South Korea spent 28.48 billion Won (approximately 23.15 million USD at 1230 Korean Won = 1 USD) in 1 year to provide direct energy aid to North Korea with items such as HFO and briquette – of which 24.458 billion Won (approximately 19.884 million USD at same exchange rate as previous) was spent paying for the HFO [32]. Therefore, if the South Korean government were to use such funds to pay for the mid- and long-term energy solution instead of paying for the short-term direct energy aid as it has been, we assess that an appropriate amount of funding could be secured to implement a policy that utilizes RE and calls for cooperative relationship with North Korea rather than a one-sided aid.

8. Conclusion

Considering the current North Korean economic and energy situation, long-term energy solution is a necessity. However, on the international political level, any assistance to and cooperation with North Korea must be approached with due circumspection and they must coincide with the current domestic energy policies of North Korea if one hopes to encourage its proactive cooperation. Any support and cooperation policy must also transfer the essential technology to the North by design so that the program can both solve the long-term energy shortage and contribute to North Korea's technology and industrial development–which addresses the issue of sustainability. Current energy aid programs such as the heavy fuel oil aid and direct power transfer causes South Korea to continuously supply the North with raw energy resources with no premise of foreseeable improvement.

There can be various positive effects on political, economical, and societal situation in North Korea by the South supporting the North with RE. By providing infrastructure support and technology transfer, we can solve the North Korean energy crisis in the long-run by addressing the core causes of the North Korean energy deficiency. Since RET presents a minimal possibility of diversion for military use, it also satisfies the international and the South Korean national security concerns, which could serve as a conduit to securing international cooperation on the humanitarian level. The policy would also effectively expand the market size for the South Korean RE industry in the long-run, and it has the effect of increasing and upgrading the energy infrastructure of North Korea.

Consequently, North and South Korea must select the most appropriate RE and RET, agree on the terms of support and cooperation in detail, and implement comprehensive policies to achieve these goals. Our research showed, however, approximately 30% of the respondents answered they had "no desire to pay" for RE support to the North. Even among those respondents who showed a positive attitude toward RE, over 20% answered "no desire to pay." Therefore, it would be difficult for SKG to implement a policy where the South Korean residents would pay the cost directly.

To overcome such reluctance, CDM projects and civilian-led projects may be used as an alternative, which are certainly possible with RE. These energy cooperation programs and projects are based on the people's understanding and interest rather than on the unilateral decisions made by the government, making the policy very attractive, which will assist with the South Korean residents' understanding and approval of the policy.

RE is the most rational choice based on our analysis. We will continue to strive to determine, from the SKG's policy perspective, the most appropriate RE source and RET that could be used in providing mid- and long-term energy solution to North Korea and fundamentally solve its energy crisis. In doing so, we not only endeavor to determine the economic feasibility of such energy development, but also seek to lead and facilitate the collaborative efforts among all sectors related to energy and energy policy within South Korea to improve South Korea's own development and usage of RE.

Acknowledgements

This research was funded by the Seoul National University Institute for Peace and Unification Studies and the Ministry of Knowledge Economy Research Center for New and Renewable (Wind) Energy Policy.

References

[1] Kim NG. Status of North Korean energy industry development. North Korea 1983;135:172–89 [in Korean].
[2] Lee SK. Changes in the North Korean industrial management system and industrial activities. Korea Institute for Industrial economics and Trade; 2003 [in Korean].
[3] Son GW. Options for supporting environmental improvement in North Korea—agricultural and energy efficiency improvement. Korea Institute for National Unification; 1997 [in Korean].
[4] Moon JY. The cost and effect of LWR Project and its implications. Unification Policy Stud 2007;16(2):233–62 [in Korean].
[5] Mortimer ND, Grant JF. Evaluating the prospect for sustainable energy development in a sample of Chinese village. J Environ Manage 2008;87:276–86.
[6] Singal SK, Varun, Singh RP. Rural electrification of a remote island by renewable energy sources. Renew Energy 2007;32:2491–501.
[7] Nouni MR, Mullick SC, Kandpal TC. Providing electricity access to remote area in India: an approach towards identifying potential areas for decentralized electricity supply. Renew Sustain Energy Rev 2008;12:1187–220.
[8] Kim K. Electric power generation from renewable energy in the DPRKorea. In: Proceedings: energy scenario in the DPR of Korea: upgrading and integration of energy systems; 2002. p. 437–42.
[9] Kim S. National 5-year R&D plan for RE. In: Proceedings: energy scenario in the DPR of Korea: upgrading and integration of energy systems; 2002. p. 501–15.
[10] DPRK Delegation. Energy futures and energy cooperation in the Northeast Asia Region. The Nautilus Institute's 2006 Asian Energy Security Workshop, Beijing, China, November 2006.
[11] DPRK Delegation. The potential impact of the inter state ties in northeast Asia on Environment. 3rd Workshop on Power Grid Interconnection in northeast Asia, Vladivostok, Russian Federation, September 2003.
[12] Jo IY. Medium–small hydropower plant, energy scenario in the DPR of Korea. In: Proceedings: upgrading and integration of energy systems; 2002. p. 451–7.
[13] Son CY. North–South cooperative development in wind power technology. North Korean Sci Technol Res 2006;4:109–24 [in Korean].
[14] Son CY. North–South cooperative development in wind power technology. North Korean Sci Technol Res 2007;5:41–60 [in Korean].
[15] Jungang Ilbo. http://article.joins.com/article.asp?Total_ID=2535831 13.12. 2006 [in Korean].
[16] DPRK Delegation. The prospect of electrical energy development in DPRK and regional co-operation in North-East Asia. 3rd Workshop on power grid interconnection in northeast Asia, Vladivostok, Russian Federation, September 2003.
[17] North Korean Economic Team. Energy research for Eunha-Ri, North Korea: methodology, results, and implications. KDI Rev North Korean Econ 2002; July: 45–63 [in Korean].
[18] von Hippel DF, Hayes P, Williams JH, Greacen C, Sagrillo M, Savage T. Rural energy survey in Unhari village. In: The Democratic People's Republic of Korea (DPRK): methods, results, and implications, May 20, 2001; 2001.

[19] von Hippel DF, Hayes P, Williams JH, Greacen C, Sagrillo M, Savage T. International energy assistance needs and options for the Democratic People's Republic of Korea (DPRK). Energy Policy 2008;36:541–52.
[20] Savage T. Introduction to the special issue. Asian Perspect 2002;26(1): 5–8.
[21] Greacen C. Nautilus team, rural re-electrification in the DPRK. Asian Perspect 2002;26(1):57–76.
[22] Small Wind Energy Development and Promotion in Rural Areas (SWEDPRA). Project Document of UNDP; 1999.
[23] VOA News. http://www.voanews.com/Korean/archive/2009-01/2009-01-01-voa6.cfm?moddate=2009-01-01 01.01.09 [in Korean].
[24] Yonhap News Agency. 01.02.09 [in Korean].
[25] Kim TH. Feasibility for new and renewable energy support for North Korea: wind power. Petrol Rev 2007;23(2):137–57 [in Korean].
[26] Lim SY, Heo EN. System design for activation of renewable energy and cooperative renewable energy plan between South and North Korea-based on the survey of renewable energy experts. J Korean Soc New Renew Energy 2005;1(3):24–34 [in Korean].
[27] Kim KJ. Research on Northeast Asian energy cooperation: potential for Northeast Asian new and renewable energy—analysis. Final Report, and Policy Research Report; 2005. KEEI, MOCIE [in Korean].
[28] Kim S. The energy policy of DPRK and energy technical cooperation field between the ROK–DPRK. In: Proceedings of 2006 The Korean Solar energy society conference, April; 2006. p. 339–43.
[29] Kahneman D, Ritove I, Schkade D. Economic preferences or attitude expressions? An analysis of Dollar responses to public issues. J Risk Uncertain 1999;19(1–3):203–35.
[30] Holcombe RG, Kenny LW. Evidence on voter preferences from unrestricted choice referendums. Public Choice 2007;131:197–215.
[31] McFadden D. Rationality for economists? J Risk Uncertain 1999;19(1–3):73–105.
[32] Ministry of Unification. South–North Cooperation Fund Statistics; 2007 [in Korean].